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SELECTED PROBLEMS IN OPERATIONAL RELIABILITY OF TELECOMMUNICATIONS NETWORKS

by

Henryk Baczko

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SELECTED PROBLEMS IN OPERATIONAL RELIABILITY OF TELECOMMUNICATIONS NETWORKS

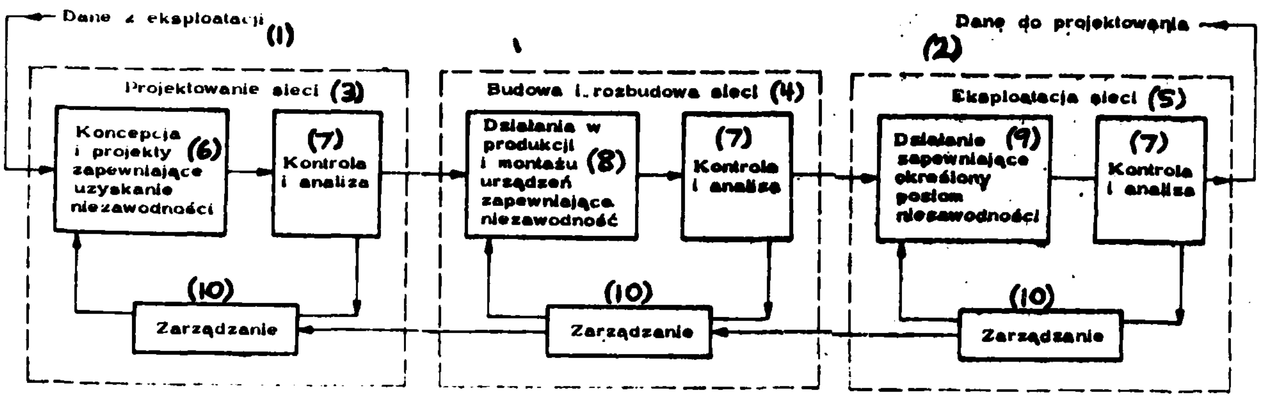
Henryk Baczko

A matter of vital importance to all branches of the economy in the nation's present stage of development is the effectiveness of their operation, and also the quality and reliability of their products. A major problem in the field of telecommunications is network operational reliability, one of the factors which determine the quality of the services provided.

In light of the new methods,the problem of reliability should be examined using a systems approach. This is fully applicable to telecommunications networks. It means that the subject of reliability should be dealt with in the integrated phases of telecommunications network planning, construction, development, modernization, and operation. Only this kind of treatment makes it possible to achieve the intended level of reliability at optimum costs, to have flexible planning, and to accomplish the necessary work.

Such a systems approach to the problem — given proper monitoring of the parameters and flow of information among the departments responsible for planning, construction, and operation of networks — permits production of more reliable facilities and use of the most advisable methods of designing and operating telecommunications networks. Below is a simplified diagram exemplifying integrated activity and circulation of information to obtain reliability in a telecommunications network.

Simplified example of integrated activity
in telecommunications network reliability



1 — data from operation; 2 — data for design; 3 — designing of network; 4 — construction and development of network; 5 — operation of network; 6 — concepts and plans for ensuring reliability; 7 — monitoring and analysis; 8 — production and assembly of facilities to provide reliability; 9 — activity providing a specified level of reliability; 10 — management

The problem of reliability in all stages of telecommunications network formation and operation is beyond the scope of this article; we shall give our attention to the operations stage. A national telecommunications network is long-lived and has great value, accumulated during the decades of its existence. It is constantly

changing, like a living organism, in which some cells are always dying, while new ones appear and develop.

Proper maintenance of this network, and especially assurance of increasingly better operational reliability (which is very true for telecommunications), are an unusually difficult task. The following problems for discussion have been selected from the broad theme of operational reliability in telecommunications networks: establishment of reliability indices; the influence of technological progress in a network's facilities on its reliability; the organization and methods of improvement in the reliability of telecommunications networks.

Problems in establishing operational-reliability indices for a telecommunications network

Before examining this subject, let us note the fact that at the present time only an insignificant part of worldwide and national telecommunications networks is devoted to anything other than telephony. Therefore, this problem, being crucial, should be dealt with first. The establishment of proper telephone-network reliability indices and their values is an extremely important stage in all work aimed at raising the level of telecommunications network reliability. These indices should be at the center of attention for all personnel, and at least some of them should be comprehensible to the recipients of telephone services. They must also be clear to all workers at the separate organizational levels in the operations sector.

The following methods are being used to establish reliability

indices: historical, comparative, voluntaristic, and statistical.

The *historical method* is based on the comparison of indices from similar periods in past years with the present. The disadvantage of this method is that in furnishing data from the past it does not define what these indices are to be in the future; this is because of the qualitative and quantitative development of the network.

The *comparative method* is burdened with errors arising out of the difficulty of weighing similarity. It can lead to the adoption of unreal indices.

The *voluntaristic method* amounts to imposition, by the administrative head at the appropriate level, of indices of the time needed for elimination of defects. In truth, these indices are usually based on observations of the past, but lack sufficient or rational grounds.

The *statistical method* is the one most often used in countries with well-developed telecommunications. In this method we rely on data from the past, which we treat as a collection of random events with normal distribution. Excluding events which are glaringly different or which result from natural calamities, and using simple transformations from the mathematics of probability, we obtain values for indices which optimally illustrate events and at the same time indicate a developmental trend. These can form a basis for establishing indices. Studies have shown that reliabilty indices calculated in this way are more readily accepted by network personnel and satisfy the administration.

Formulation of indices normalized only for failures occurring in the course of normal operation requires special treatment of

failures which result from natural disasters such flooding, mining damage, and storms. In these cases specific situations which might arise are analyzed individually, with special attention being devoted to a telecommunications network's capacity to withstand a given natural calamity, and also the efficiency of personnel in locating damage and restoring normal communications. As a result of analysis, of course, steps are taken to eliminate shortcomings. Research shows that if failures during natural calamities are included in the statistics on failures in normal operation, the state of reliability of a telecommunications network is obscured. Personnel, especially those maintaining the network in disaster areas, are also dissatisfied with this kind of approach, because it makes objective assessment of their efforts more difficult.

Indices accepted as standard should designate tolerances within which deviations from a required level of reliability are permitted. These indices can be made more stringent for certain services. An example would be a dedicated data transmission network within a larger telecommunications network. Standard indices of reliability can also be specified for leased networks.

Standard indices of reliability which apply to a whole country or some other large area can be differentiated (made more stringent or less stringent) for certain regions, or even for individual exchanges and trunk lines with specific features which significantly influence conditions for preventing and correcting failures. Obviously, standard indices of reliability for telecommunications networks of individual areas must be such that the standard indices for the country or region as a whole can be observed. Therefore, if a

certain value of the availability factor $K_g = \bar{T}/(\bar{T} + \bar{T}_n)$ were a standard index of reliability for the national telephone network, it would be necessary to satisfy the inequality

$$K_g > \prod_{i=1}^{n} K_{gi},$$

where:

$\bar{T}$ — mean time of correct network operation,

$\bar{T}_n$ — mean time of network restoration,

K_{gi} — values of availability factors for telephone networks of individual regions.

Standard reliability indices of telecommunications networks should be systematically reviewed and modified as new technical and operating conditions arise. An essential condition for establishing adequate standards of reliability, i. e., standards which best correspond to the actual technical and operating potential of a network, is to base them on frequent monitoring. If, for example, we adopt the number 8 as the standard for the number of failures registered monthly for 100 telephones, frequent monitoring will verify whether this is a realistic standard or not. Only in this way is it possible to obtain, in accordance with statistical laws, data which are closest to reality. If monitoring of network operation is reduced, there may be negative effects on personnel morale, as well as a reduction of the validity of standard indices of reliability.

In spite of the fact that establishment of standard indices of reliability is laborious and tedious, with the present state of the art of telecommunications networks the proper level of services cannot be assured without such indices. It can even be stated — on the basis of foreign studies — that intermittently imperfect standards

are better than none at all.

A good example is the Japanese telecommunications system, which is a leader not only in the number of telephones, but also in methods of network maintenance. New methods of operation have been introduced in connection with the vigorous development of telephony in Japan (in recent years the number of subscribers has grown 13-fold, reaching 26 million in 1975, second only to the USA), and a very important element in these methods is standard indices of operational reliability. The standard introduced in 1957 for monthly reported failures per 100 telephone subscribers was 5; it was achieved by only 10% of the telephone offices at first, but the percentage gradually increased, until all the telephone offices in Japan achieved the index of 5 in 1973. However, the mean value of the level of service achieved was 1 failure monthly per 100 subscribers. This means that if failures were evenly distributed among all subscribers, each subscriber would encounter a failure once in 8 years.

In 1973 the standard index for reported failures on leased intercity trunk lines was 15 min per line monthly; it was achieved by 97% of the lines. The average value achieved was 4.4 min, which means that the availability factor for this type of line was 0.9999. Such remarkable results were due in large part to the introduction of up-to-date switching, transmitting, and testing equipment into the operations of the Japanese telecommunications system.

The influence of technological progress in telecommunications network facilities on network operating reliability

Technological progress in telecommunications is very rapid. New types of equipment and systems with increasingly complicated structures are continually appearing. The quantitative development of telephony has made the telecommunications network broader, more dense, and more complex, and thus increasingly subject to failures. For this reason ever more stringent reliability requirements are being established for modern equipment and systems. With the introduction and proper operation of the latter it is possible to improve the reliability of an entire network significantly.

Poland has been introducing new crossbar (PENTACONTA) and electronic (DIT-10) switching systems for which licenses were purchased. Telephones have also been improved by a new dial. New cable-manufacturing technology has been used in the field of long-distance transmission. A lack of research prevents evaluation of the influence of these new systems and equipment on network reliability. In view of this, it might be advisable to tell how the process has taken place in other countries.

In Japan the number of failures in urban telephone networks has been radically reduced by the introduction of new types of exchanges for the CP 400 crossbar system, the 600 model telephone, and CCP subscriber's cable. The effects are well illustrated by the table below, which appeared in the "Telecommunication Journal of Australia", nr 1, 1976, p. 45.

Nowo wdrożone urządzenie (1)	Rok wdrożenia (2)	Udział w tego rodzaju urządzeniach w % (3)	Poprawa pracy urządzeń — zmniejszenie liczby uszkodzeń (4)	Wpływ na eksploatację (5)
Aparat telefoniczny typu 600 (6)	1964	85	o 20% w stosunku do starych typów aparatów telefonicznych (7)	zmniejszona została pracochłonność dzięki redukcji uszkodzeń (8)
Kabel abonencki w powłoce z mas plastycznych CCP (9)	1963	97	o 20% w stosunku do kabli z płaszczem ołowianym (10)	jak wyżej oraz nastąpiła poprawa pracy kabli (11)
System krzyżowy CP 400 (12)	1966	76	o 20% w stosunku do telefonicznych systemów komutacyjnych skokowo-obrotowych (13)	dotychczasowe prace konserwacyjne zostały udoskonalone technicznie (14)
Elektroniczne urządzenia sygnalizacyjne (15)	1967	56	(16) o 33% w stosunku do urządzeń systemu „rotary"	pracochłonność przy konserwacji zredukowana (17)

KEY: 1 — equipment introduced; 2 — year of introduction; 3 — percentage of this type of equipment; 4 — improvement in equipment operation - reduction in number of failures; 5 — effects on operation; 6 — Model 600 telephone; 7 — 20% over older telephone models; 8 — labor saved because of fewer failures; 9 — CCP subscriber's cable with plastic sheathing; 10 — 20% over lead-covered cable; 11 — same as above, and also improved cable performance; 12 — CP 400 crossbar system; 13 — 20% over step-by-step rotary telephone switching systems; 14 — maintenance work technically improved; 15 — electronic signalling equipment; 16 — 33% over rotary system equipment; 17 — labor for maintenance reduced

As automation of intercity traffic in Japan progressed, operating problems became increasingly complicated. Failures on long-distance routes impeded telephone connections not only between the points directly affected, but, because of the operation of senders and bypass routes, between other points as well; the latter paths

were overloaded by rerouted calls. The central office had to intervene in this situation, because the effects of the failure were keenly felt throughout the country. On account of the above, new equipment came into use in 1965 — a toll transit switch, which was installed in all regional centers; with this an up-to-date centralized operating system began. In this way the central office and the regional operations centers acquired new capabilities for monitoring and exchanging information on the state of the network. As a result of these measures, in 1973 there was an average 0.003 failures reported per 100 subscribers making intercity telephone calls.

In the USA — according to a national telecommunications conference in New Orleans (1975) — an availability factor of $K_g = 0.999973$ has been achieved at installed electronic telephone exchanges. At a 1972 symposium on reliability held in San Francisco it was reported that the use of pressure in high-capacity local telephone cables reduced failures by 35%.

At a symposium in London (1975) British telecommunications administrators furnished interesting data on the effectiveness of using redundant systems and switch-over systems in long-distance, cable, and radio links. It was found that in a 4 MHz system the down-time factor $K_p = \bar{T}_n/(\bar{T} + \bar{T}_n)$ for radio lines, where: $\bar{T}$ — mean time of correct operation of link between points 100 miles apart, and $\bar{T}_n$ — mean time for restoration of link between points 100 miles apart, is one-third as large as the down-time factor for mixed cable and radio links. This was achieved by using reserve channels and automatic switch-over equipment on radio lines.

A similar technique of automatic connection of reserve

facilities has been used by Bell Telephone in the new L5 coaxial cable system. In this case the length of the reserve segment of cable can be adjusted for a desired level of reliability and costs. The new switch-over equipment and monitoring and testing equipment makes it possible to reduce costs, but also is a cause of failures due to its own complexity.

Factors other than the rapid technical progress in telecommunications continue to have an important role — perhaps more important than before — in improving the reliability of telecommunications networks: personnel skills, work organization, availability of monitoring devices, spare materials, repair tools, and transportation. The degree to which signalling and localization are automated, the quantity, variety, and location of emergency backups, the accessibility of equipment and the use of interlocking systems, the degree of standardization, the interchangeability of subassemblies and elements — all of these have a bearing on the maintainability of a network. The term "communications network maintainability" embraces those features of a network — aside from the work of the operating personnel — which ensure the signalling, locating, and correction of faults occurring in the network.

How the organization of telecommunications network operation affects its reliability

The operating reliability of a telecommunications network is greatly influenced by network maintenance methods. *Preventive maintenance* of a telecommunications network is a group of measures in which incipient faults are searched for, investigated, and eliminated before

they develop completely. Preventive maintenance has a vital role in reducing the number of failures arising from use. This type of failure can be foreseen, and the work which results from this fact is a constant element in the activities of the personnel who service a telecommunications network.

The *corrective method* of telecommunications network maintenance is a group of measures for monitoring, investigating, and eliminating faults in order to permit accomplishment of tasks assigned to the network.

The choice of either of these methods, or both (which is most frequently the case) depends upon operating cost ceilings and upon the required level of network preparedness. The decision as to how much each of these methods will be applied requires thorough knowledge and stabilization of network operating conditions. In the event of a change in the situation, such as modernization, cost-cutting policies, or more stringent reliability requirements, a review of maintenance methods is necessary.

Often, in order to improve telecommunications network operating reliability, managers focus their attention on the weakest individual elements in the network (e. g., old cable, worn-out equipment) and show less concern for the rest of the network. Very often this is wrong. Calculations based on the mathematics of probability show that improvement of the weakest element in a developing network does increase the latter's reliability, but the effectiveness of this approach is low. In order to improve the reliability of the entire network, it is more effective to improve the reliability of elements of telephone links,which are less frequently subject to failure but are more numerous. It is important for the operators of a telephone

network to take the statements above into consideration.

The final link in the telephone chain is the subscribers. The reliability of services depends to a considerable degree upon the users' familiarity with the rules of telephone use. The efforts of all the personnel serving the coaxial cables, radio links, and various long-distance systems are of no avail if the subscriber cannot use the telephone properly. The automation of intercity telephone traffic has made it especially important to inform and educate subscribers. This requires effective information service, systematic issuance of telephone books, and publicity in all available media (posters, brochures, leaflets, folders, radio, and television).

Considerably more attention should also be given to maintenance of subscriber equipment, especially telephone sets. Telephone subscribers are not only a vital factor in the proper functioning of the telephone network; they are also an exacting collective monitor of its performance. Administrators have various methods of obtaining the services of this collective monitor and consultant. In Japan, for example, certain indices of telephone network reliability are released to the public for continuous verification. Subscriber complaints are one of the primary measures of telecommunications network performance.

Other countries have organizations of telephone users. In these associations representatives of the users consult with management and telecommunications equipment manufacturers about improving the reliability and quality of telephone service. Opinion-sampling methods are also employed among specific groups of telephone users.

In discussing the future, it should be noted that research on the construction of up-to-date, increasingly sophisticated telephone

networks indicates that no tests or calculations (which are necessary in designing networks and manufacturing equipment) can completely define network reliability.

The use of computers in switching has brought a number of indisputable advantages, but also problems with software reliability. Research in the USA has shown that failures resulting from certain errors in the programming of control computers can only be found and corrected during operation, sometimes after several years have passed.

These considerations point to the continuously growing significance of operational reliability as an increasingly decisive factor in the correct functioning of telecommunications networks, both now and in the future.

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